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AID Report T-63-49

17 April 1963

PHOTOMETRY OF SOLAR FLARES

Translation

AID Work Assignment No. 35
(Task 8a)

Aerospace Information Division
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AID Report T-63-49

NOTE: This translation constitutes the first report issued in response to AID Work Assignment No. 35 Task 8a. Subsequent reports published in response to this Work Assignment will be numbered serially on the cover.

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17 April 1963

PHOTOMETRY OF SOLAR FLARES

Translation

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PHOTOMETRY OF SOLAR FLARES

This article was originally published as follows:

Karimov, M. G., A. S. Zubtsov, M. I. Antushevich, and S. K. Dosybayev. Fotometriya solnechnykh vspyshek. IN: Akademiya nauk Kazakhskoy SSR. Astrofizicheskiy institut. Izvestiya, v. 14, 1962, 93-106.

This study gives the results of the photometric processing of solar flares of importance ≥ 2, observed from October 1957 to the end of 1959, i.e., during the International Geophysical Year and the International Geophysical Cooperation.

The observations were made at a high-mountain coronal station, 2600 m above sea level, in the region of Great Alma-Ata Lake (Bol'shoye Almatinskoye Ozero), with the aid of the type-AFR-2 chromosphere-photosphere telescope.

The motion picture was made in the H_α line with an interference-polarization filter having a pass-band width of 0.6 A. Standard 35-mm panchromatic high-sensitivity (1000-1200 GOST Units) photographic film was used. The rate of filming was 2 frames a minute (sometimes 8 or 4).

Standardization and calibration were effected through the insertion of a reducing screen with nine degrees of transparency, illuminated by the solar disk. In accordance with international instructions, the screen was inserted during normal, twice-normal, and four-times-normal exposures.

The films were developed using the standard contrast-type fine-grain developer.

Observational Data

The photographic films obtained of the flares were processed with a type-MF-2 microphotometer for determining intensity, and with a spectrophotometer for determining the flare area.

Individual characteristic flare condensations were photometered. Last of all, the intensities of the individual nodes were determined, expressed in units of intensity of the undisturbed region of the solar disk close to the flare.

All the frames were carefully examined beforehand; those with defects were discarded. The micrometer diaphragm was selected so as not to be larger than 2/3 of the image of the individual nodes of the flares.

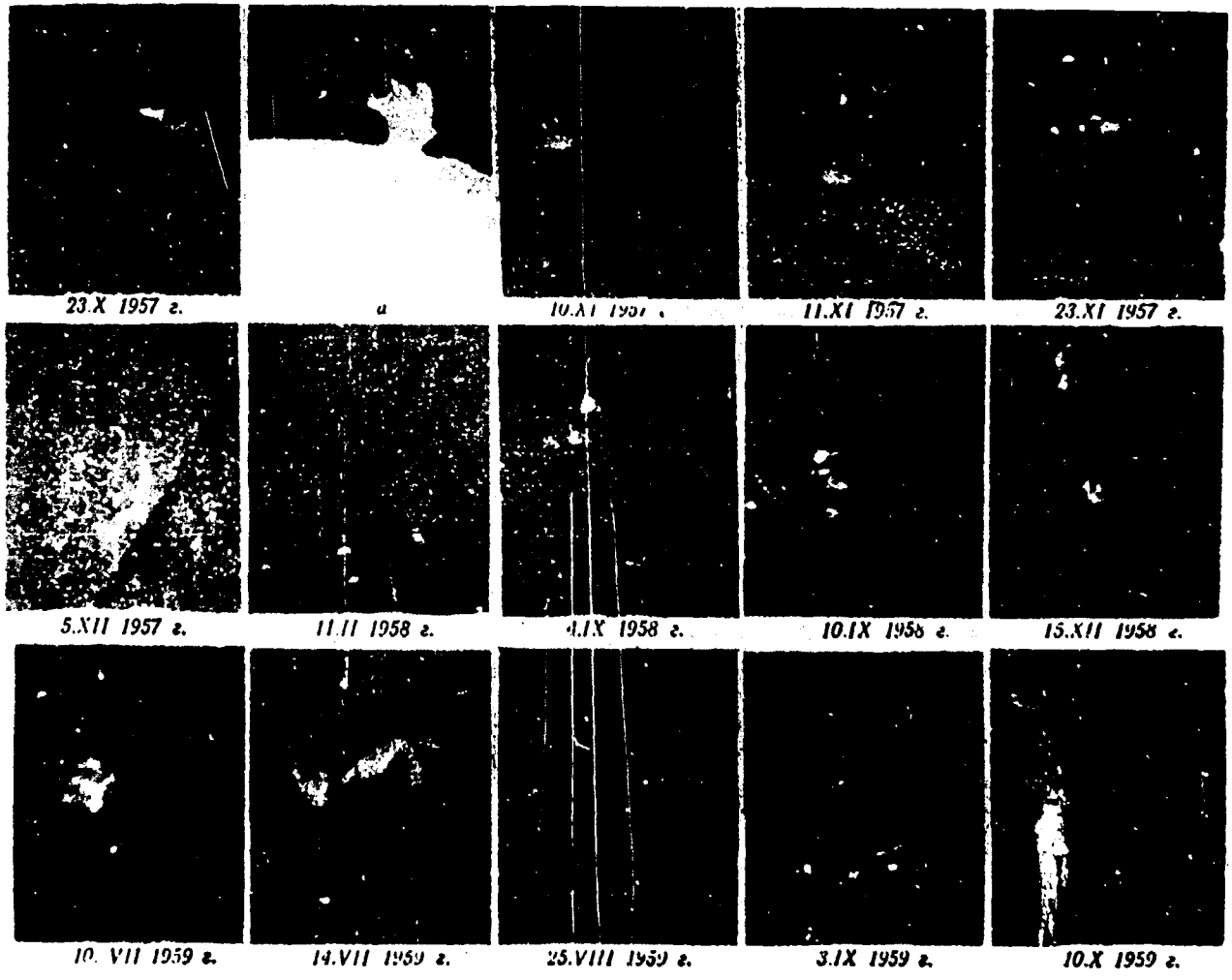
23.X 1957 г.
11.XI 1957 г.
23.XI 1957 г.
5.XII 1957 г.
11.II 1958 г.
10.IX 1958 г.
15.XII 1958 г.
10. VII 1959 г.
14.VII 1959 г.
25.VIII 1959 г.
3.IX 1959 г.
10.X 1959 г.

Fig. 1

Date	Observation time		Location			Imp.	Remarks
	Onset	End	Lat.	Long.	L.		
1957							
	h m	h m					
23 Oct	6 21	6 32	-27°	+77°	245°	2	Normal film; good observation conditions
2 Nov	9 04	9 43	-20	+16	239	2	Normal film; good observation conditions
10 Nov	7 00	7 30	-24	-65	054	2	Film strongly overexposed
11 Nov	6 28	6 40	-24	-52	054	2	Film strongly overexposed
23 Nov	8 05	8 15	+27	+54	001	2	Photography through cirrus from low to average density
5 Dec	5 52	8 01	-19	+21	170	2	Band good; film overexposed
1958							
11 Feb	8 15	8 45	-11	+85	058	2	Photography between clouds; band good
5 Jul	3 46	4 35	+27	-07	224	2	Satisfactory observation conditions
4 Sep	5 09	5 20	+19	-80	066	2+	Film slightly fogged; flare onset not observed
16 Sep	4 20	5 19	-18	-40	309	2	Good observation conditions
15 Dec	6 25	6 40	+25	-21	219	2	Film has general fog
1959							
10 Jul	2 57	5 38	+18	-63	327	3	Observation conditions diminished; photography interrupted by cloudiness
14 Jul	3 26		+18	-09	328	2+	Picture jumping

(Continued from p. 3)

Date	Observation time		Location			Imp.	Remarks
	Onset	End	Lat.	Long.	L.		
1959							
23 Aug	3 17	3 41	+08	+37	205	2	Photography through cloud breaks
25 Aug	4 57	5 23	+02	+66	206	2	Photography through cirrus
3 Sep	4 21	4 35	+26	+83	092	2	Film underexposed
10 Oct	3 26	5 46	-19	+47	301	2	Photography through clouds; screened frames discarded

The areas were measured on the basis of those frames used in the measurement of intensities.

Photographs of the flares are shown in Fig. 1. The table gives a list of the processed flares for the period from 23 Oct 1957 to the end of 1959. Observation times are given in universal time.

Columns 1, 2, and 3 indicate (respectively) the date of observation, the time at beginning of observation, and the time at end of observation. The actual beginning and end are underlined. The latitude, longitude, and angular distance from the Carrington meridian are given in the fourth, fifth, and sixth columns. The importance of the flare, determined on the basis of two quantities -- intensity and area -- is given in the seventh column. The observation conditions and the quality of the films obtained are indicated at the end of the table [i.e., in the eighth column].

Characteristics of Individual Flares and Curves of Flare Development

The flare development curves were constructed for the most clearly defined individual nodes.

On the intensity-time graphs the ratios of the intensity of the individual node to the intensity of the undisturbed area of the solar disk are plotted along the Y-axis, while the time is plotted along the X-axis.

On the graph showing the relationship of area change with time, the value of the area is plotted along the Y-axis. Inasmuch as both graphs are given together, the intensity is given from the left along the ordinate, while the value of the area is given from the right. The common time is plotted along one X-axis.

In addition, a sketch of the flare showing all the spot and flocculus-field details is given in the upper right corner of the graphs. Specific areas are indicated as follows: 1) foci of flares: solid black area; 2) flocculi: crosshatched areas; 3) spots: closed contour lines with a dot inside; 4) filaments: simple contour lines.

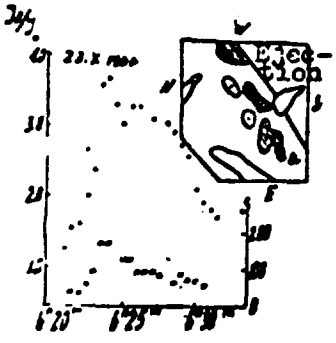

Fig. 2

Flare of 23 Oct 1957. This flare developed at the solar limb in the region of a bipolar spot group. The brightness of the flocculus (a) grew. At 6^h24^m a very bright ejection appeared in the flare region and continued to exist after this as an active sunspot prominence. The velocity of the ejection was 389 km/sec. Movement of individual details of the prominence took place along the lines of force of the dipole field at a velocity of 175 km/sec from 6^h32^m to 6^h36^m.

At 6^h32^m the height of the prominence was $133 \cdot 10^3$ km, and at 6^h36^m it was $175 \cdot 10^3$ km. It remained almost constant up to 6^h50^m. From 6^h50^m to 7^h10^m the prominence subsided at a rate of 30 km/sec, losing brightness in the process, and disappeared completely at 8^h00^m (Fig. 2).

Flare of 2 Nov 1957. This consisted of a number of bright details. Next to spot (a) was a weak flocculus (the central part of node 1). Starting at 9^h04^m the brightness of the flocculus began to increase. Node 2 appeared at 9^h06^m, and node 3 appeared at $9^h10^m.5$ in the form of a faintly luminous point. The area of brightness center 3 changed slightly. Node 1, in which the intensity increased by jumps, was the most characteristic. It had an elongated pear-like form. The node had weakly defined secondary maxima of intensity and area. The brightness-growth parameters for the three nodes were $P_1 = 0.136$, $P_2 = 0.096$, and $P_3 = 0.109$, respectively. Node 1 expanded partially from the SE to the NW. The main direction of movement of this node was westward (Fig. 3).

Flare of 10 Nov 1957. This flare developed not far from the solar limb. Before the flare of importance 2 (from $6^h12^m.5$ to 6^h45^m, with maximum at $6^h21^m.5$), a flare of importance 1 was observed. After the weak flare a flocculus of average brightness remained.

The flare of importance 2 was accompanied by an ejection moving along the radius at velocity V = 650 km/sec from $7^h01^m.5$ to 7^h06^m. The brightness of the flare region located in peripheral proximity to the flocculus did not vary appreciably (Fig. 4).

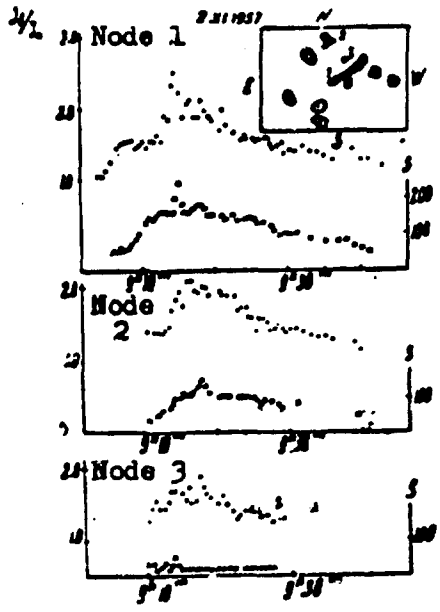

Fig. 3

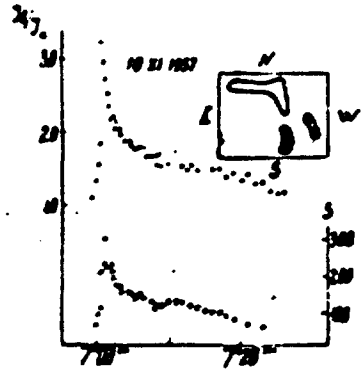

Fig. 4

Fig. 1 shows a photograph of the flare at the moment of maximum brightness, and also at the moment of the maximum phase of ejection development. It is possible to get some idea of their rapid increase from the graph showing the change of intensity and area with time. In all, 30 sec passed from the moment of onset to the intensity maximum. The area maximum lagged by 15 sec. The intensity drop after the maximum took place very abruptly up to 7^h05^m, after which it became more moderate.

Flare of 11 Nov 1957. This flare developed not far from the solar limb. At first it consisted of two bright details, which joined into one at 6^h32^m. Flocculi ringed the flare as individual details. In addition to the principal intensity maximum, there was a secondary one at $6^h34^m.5$.

The area-change curve had only one maximum, which preceded the principal intensity maximum by 30 sec. The brightness growth parameter was P = 0.644 (Fig. 5).

Flare of 23 Nov 1957. The beginning of the flare was not fixed because of cloudiness. It is possible that it was accompanied by an ejection. The brightness maximum occurred between 8^h06^m and $8^h09^m.5$. (A break in photography due to cloudiness made it impossible to determine the maximum exactly). Two flocculi were present to the NW and SW of the flare. There was a single spot between them, near which a flare developed (Fig. 6).

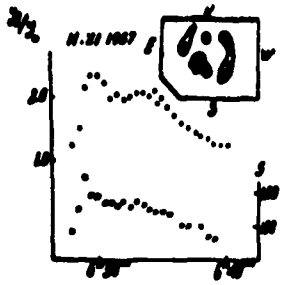

Fig. 5

Fig. 6

Flare of 5 Dec 1957. This extremely complex flare consisted of a number of characteristic brightness centers. At the beginning of the observations at 5^h52^m, the flare consisted of nodes 1, 3, and 4. Node 3 was represented by its western half, which was broken down into three equal smaller nodes; node 4 was represented by its base, and did not have any branches. The eastern edge of node 3 drew close to the western edge of node 4, as a result of which an unbroken, smoothly curved arc was formed. Under the western edge of node 4 there was a scarcely discernible fourth and smaller node of main node 3. The smaller node subsequently developed in a westerly direction and joined up with the remaining part of node 3.

At $6^h11^m.5$ the southern part of the flare, indicated on the sketch by a broken line, appeared. At maximum brightness ($7^h24^m.5$) the flare consisted of nodes 1, 3, and 4. By this time node 3 had lost its eastern half, with the eastern end deflected to the north. At the end of the observations (8^h01^m) weak node 1 and the northern offshoot of node 3 remained.

The characteristic feature of the flare was that its nodes in the majority of cases were framed with filamentary threads. Several maxima were noted in the development of intensity and area, particularly in the region of node 1 (Fig. 7).

The flare of 11 Feb 1958 developed at the western solar limb in an active region, with a band stretching parallel to the equator up to the central meridian. The form of the details at the beginning of the flare are shown in the sketch.

By the moment of maximum brightness (5^h25^m) there remained of the flare the very brilliant southern part of node 1, in the form of two smaller nodes, without, however, any clearly defined boundary. Consequently, their overall area was taken as the area of the node.

The southern component of node 1, which was the largest and brightest, stretching from the SE to the NW, touched the solar limb with its western edge, but no signs of the emersion of this detail directly on the limb were detected.

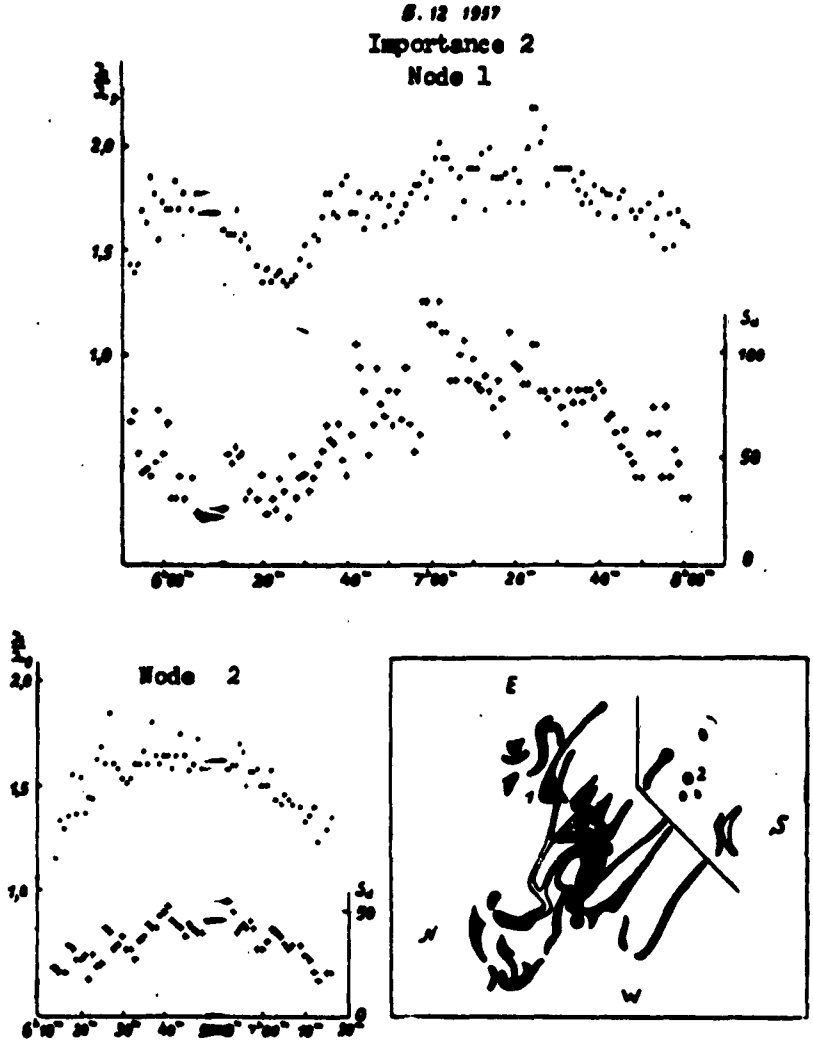

Fig. 7

By the end of these observations (8^h45^m) the dimensions and brightness of the indicated details of node 1 became the same; their brightness did not differ from that of the flocculus.

It can be seen from Fig. 8 that with the onset of the intensity maximum the area did not increase, but rather decreased. Only a few minutes later the area had increased.

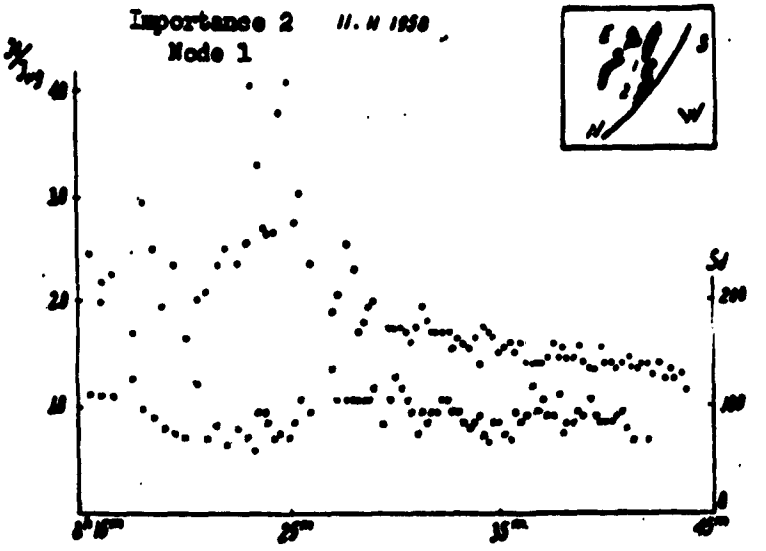

Fig. 8

The flare of 5 July 1958 developed in the vicinity of flocculi near two spots of low brightness. After the disappearance of the flare, which consisted of three nodes, the brightness of the flocculi noticeably increased. All the nodes flared up at approximately the same time; subsequently their brightness diminished very slowly. The area of the first node had a characteristic maximum at 3^h59^m. Such a sharp rise and fall was not observed in the two other nodes (Fig. 9).

The flare of 4 Sep 1958 developed not far from the solar limb close to a flocculus. The onset of the flare was not noted. It was probably in the time interval from 5^h02^m to 5^h06^m. The flare was accompanied by a weak ejection (Fig. 10).

The flare of 16 Sep 1958 appeared in the region of spot groups close to a big spot. Before the appearance of this flare, a flare of importance 1 had been in this region. The intensity of the flocculus before and after the flare remained almost constant.

The flare consisted of three characteristic nodes, which arose at different times. Node 1 appeared first, node 2 appeared 5 minutes later, and after 14 minutes node 3 appeared.

As is seen from Fig. 11, the intensity maxima of all the nodes coincide with an accuracy of up to 1 - 2 minutes. The area of the first node increased and reached a maximum at 4^h52^m. This maximum lagged three minutes behind the intensity maximum. The slope of the area curve after the maximum was steeper in comparison with that of the curve during area growth.

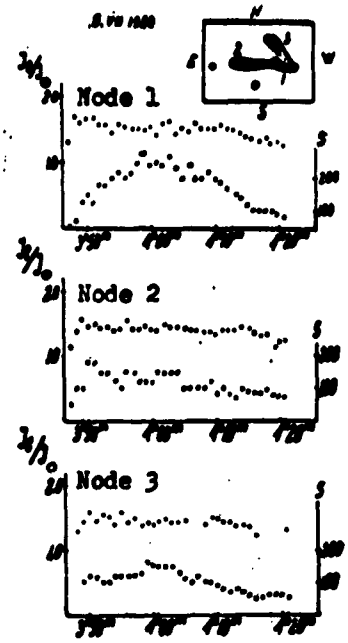

Fig. 9

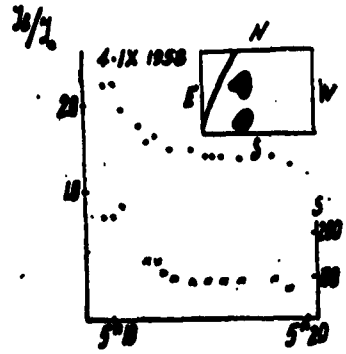

Fig. 10

As is seen from Fig. 11, the intensity maxima of all the nodes coincide with an accuracy of up to 1 - 2 minutes. The area of the first node increased and reached a maximum at 4^h52^m. The maximum lagged three minutes behind the intensity maximum. The slope of the area curve after the maximum was steeper in comparison with that of the curve during area growth.

After an increase, the area of the second node remained at a constant value for 10 minutes. The area of the third node increased sharply. The intensity maximum with the characteristic peak was more sharply pronounced, whereas the maximum of the node areas did not have such a character. The flocculi had characteristic alignments from spots to flares.

The flare of 15 Dec 1958 appeared in the region of a bipolar spot group and consisted of two details. Before 6^h25^m there was a dull flocculus in the region of spot (a). From 6^h26^m on, a movement of node 1 took place in a NW and, partially, NE direction. At 6^h30^m node 2 separated from the main mass. The brightness of flocculus (b) changed. The development of node 1 was accompanied by two intensity maxima. The area at the moment of the maximum did not change for 7 minutes. The drop of the area curve in time took place very abruptly.

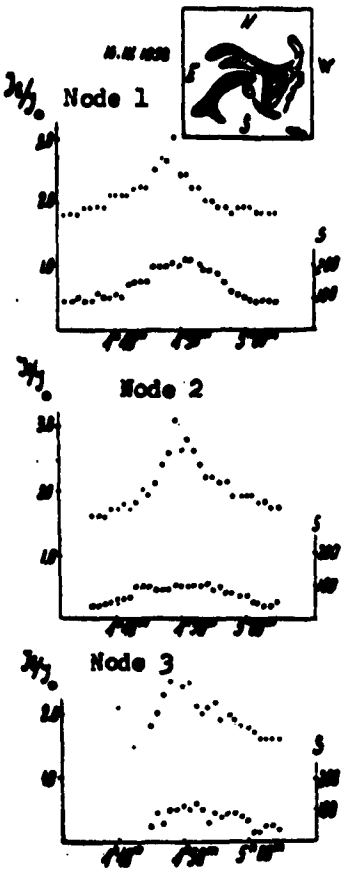

Fig. 11

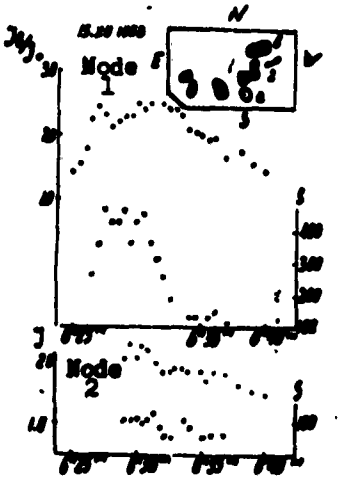

Fig. 12

The second node was not particularly characteristic, judging from the change of intensity and area with time (Fig. 12).

Flare of 10 July 1959. An emerged flare was observed in the region of a spot group. The central spot of the largest area was equidistant from the other spots. The flocculus field had individual streamers emanating from the general field. The most characteristic node (1) was located between the central and the northwest spots. Node 2 was in contact with a spot on the south side. Node 3 developed as an ejection from node 1. The velocity of the ejection was on the average 35 km/sec. The movement of the ejection took place along a streamer of the flocculus in the direction of a separate spot southeast of the first node.

In node 1 the course of the intensity and area at maximum repeats. At the end of the lifetime, the area of the node decreased

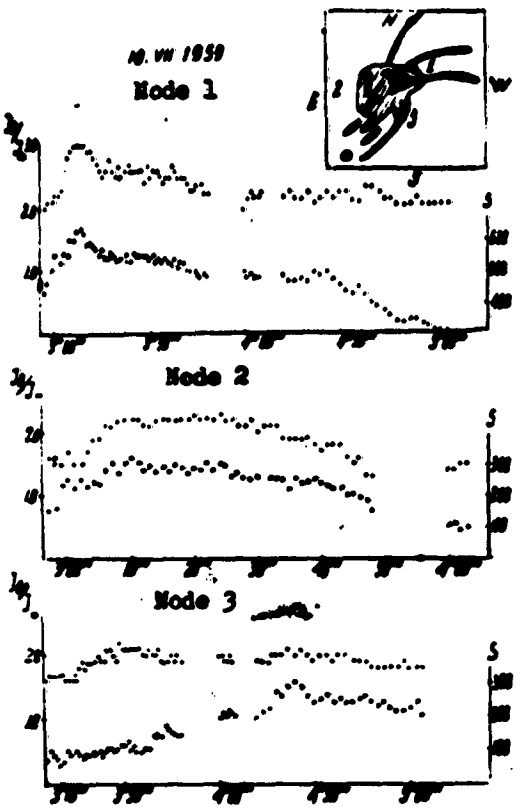

Fig. 13

with greater sharpness than the intensity. In node 2 the courses of the intensity and area coincide; there are no marked maxima. In node 3 the intensity maximum is at 3^h29^m. At the beginning of development this node was a very compact formation. The area increased gradually and attained a maximum at 4^h24^m. In this case the intensity and area maxima did not coincide (Fig. 13).

Flare of 14 July 1959. A flare of importance 3^+ arose in the region of a spot group at 3^h26^m and subsequently had a very complicated evolution. It consisted of seven principal nodes. The individual nodes arose at different times. First, node 1 appeared. The appearance of two intensity maxima in the evolution curve was noted. At the end of the lifetime of the node an increase in brightness took place, with a subsequent sharp drop. At the same time, the pattern of area change was different. At the moment of maximum the intensity of the area increased, with a subsequent drop, and then increased again approximately 1.5 times in comparison with the first maximum.

The brightness, at the same time, did not increase. Apparently, the flare was accompanied by a great rise, as a result of which the area increased, but the brightness, on the other hand, dropped. The rate of movement of this node in an easterly direction from 3^h40^m to 4^h40^m was on the average 24 km/sec.

At 3^h34^m nodes 2 and 3 arose, and somewhat later nodes 4 and 5.

Nodes 2 and 3 were not very characteristic; a certain lack of coincidence of the intensity and area maxima is noted. The intensity of the fifth node grew rapidly, attaining a maximum in 2 minutes. The area remained almost unchanged.

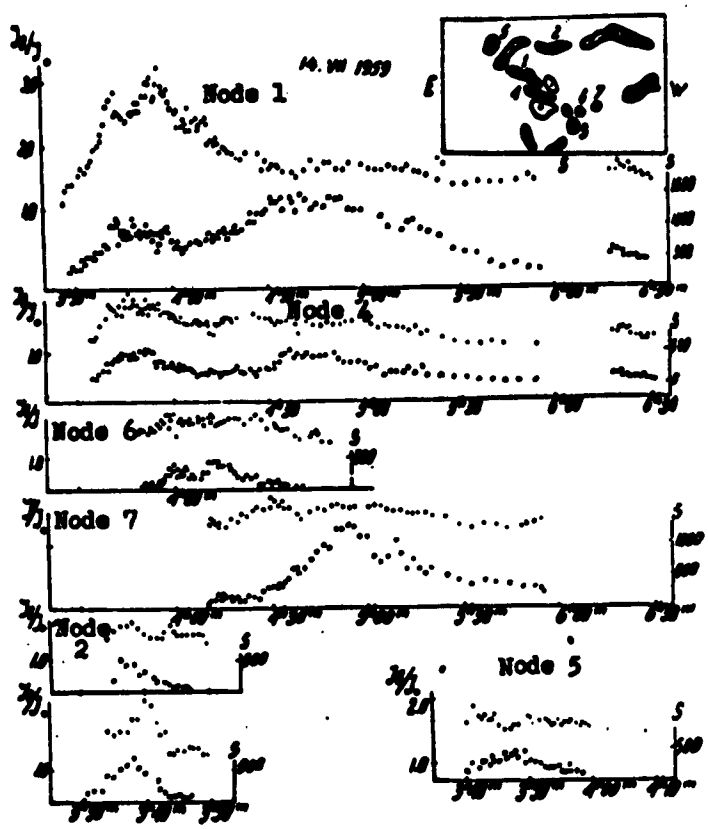

Fig. 14

The area maxima of nodes 1, 4, and 7 coincided. This coincidence was most marked in the first and seventh nodes. The area growth of node 7 took place more rapidly in comparison with the other nodes. However, the intensity increased evenly, but did not reach a particularly marked maximum (Fig. 14).

Flare of 23 Aug 1959. Observations were made through breaks in the clouds. The flare appeared in the region of a flocculus field consisting of six details, north of a separate spot. The flare area at maximum coincided with the area of the flocculus to the north of the flare. The intensity and area maxima coincide (Fig. 15).

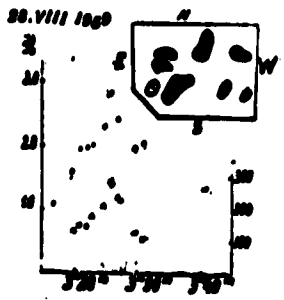

Fig. 15

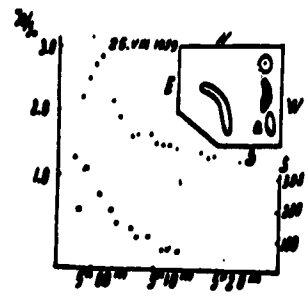

Fig. 16

The flare of 25 Aug 1959 developed near a spot from a dull flocculus in the form of a bright point. Then it spread out to the south, taking in the region of flocculus (a); the bright point stood out in its intensity. A very rapid growth of area was noted. The area maximum preceded the intensity maximum by 2 minutes (Fig. 16).

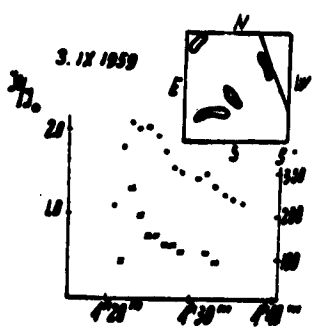

Fig. 17

The flare of 3 Sep 1959 developed at the solar limb. A very rapid area growth was noted. The area maximum coincided with the intensity maximum. There was a very weak secondary maximum of intensity and area. The flare was stretched out in a NS direction (Fig. 17).

The flare of 10 Oct 1959. At the beginning of the observation the flare was represented by only two small nodes, which subsequently formed the eastern part of node 1. The results of the measurement of these small nodes are indicated by little crosses on the graphs of brightness center 1. The results of the measurement of the two other nodes formed in the eastern and northwestern parts of node 1 after its decay are indicated by small circles and triangles.

At the brightness maximum ($4^h09^m.5$) the flare consisted of nodes 1 and 4 and was of importance 1+.

The western part of the flare, which was of importance 2 at the brightness maximum (5^h02^m) and which is indicated on the sketch by a broken line, appeared at 4^h56^m. Towards the end of the observations the flare under study was represented by its main nodes, which were still sufficiently bright (Fig. 18).

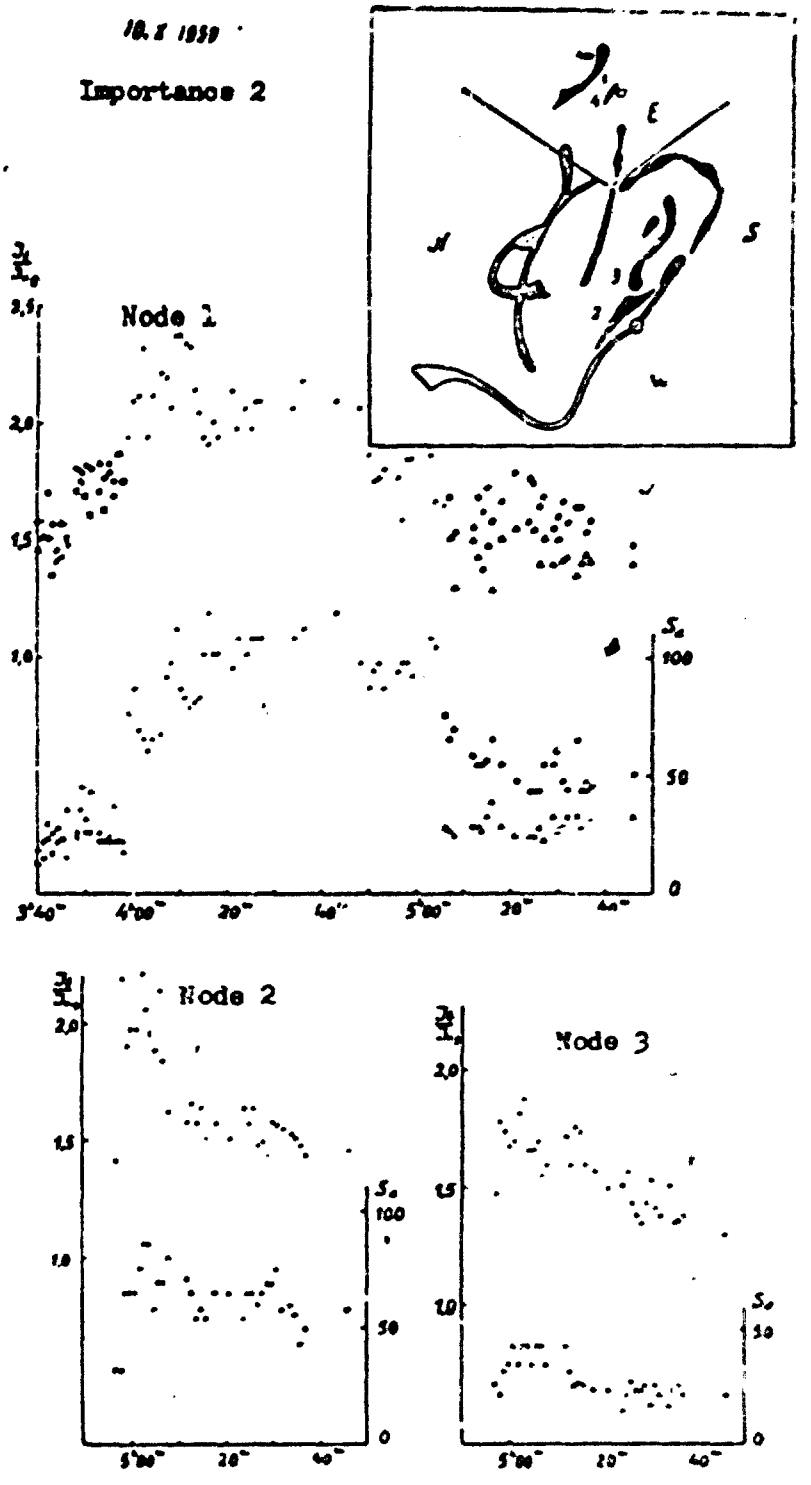

Fig. 18